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SPOTLIGHT ON soft tissue

Differentiation, Diagnosis, and Treatment of Osteoarthritis, Osteonecrosis, and Rapidly Progressive Osteoarthritis

Robert Pivec, MD; Aaron J. Johnson, MD; Steven F. Harwin, MD; Michael A. Mont, MD

Abstract: Osteoarthritis, osteonecrosis, and rapidly progressive osteoarthritis are hip arthropathies that result in marked pain and disability. Although these diseases share features of arthritis-like symptoms and are all treated with total hip arthroplasty, they are separate diseases with distinct epidemiologic, radiographic, and histopathologic findings. In this article, the authors present clinical tips and techniques that will aid the surgeon in diagnosing and treating these different entities.

Total hip arthroplasty (THA) has become the treatment of choice for multiple congenital and acquired hip arthropathies over the course of the past half-century.[1,2] Currently, approximately 500,000 of these procedures are performed yearly in the United States alone, and their number is projected to increase 174% over the next 2 decades.[3] The majority of these procedures are performed for osteoarthritis, but osteonecrosis has been estimated to represent up to 10% of all total hip arthroplasties performed in the United States.[4,5]

The differentiation between these conditions may be challenging, particularly early in the disease process. This article provides concise tips and techniques for the diagnosis and treatment of these diseases, with particular attention to their distinguishing epidemiologic, clinical, radiographic, and histologic features, as well as nonsurgical and surgical treatment options.

The authors are from the Rubin Institute for Advanced Orthopedics (RP, AJJ, MAM), Center for Joint Preservation and Reconstruction, Sinai Hospital of Baltimore, Baltimore, Maryland; and the Adult Reconstructive and Joint Replacement Service (SFH), Beth Isreal Medical Center, New York, New York.

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Correspondence should be addressed to: Michael A. Mont, MD, Rubin Institute for Advanced Orthopedics, Center for Joint Preservation and Reconstruction, Sinai Hospital of Baltimore, 2401 W Belvedere Ave, Baltimore, MD 21215 (mmont@lifebridgehealth.org).

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Overview and Epidemiology

Osteoarthritis is a chronic disease of the articular cartilage and subchondral bone. It is often multifactorial in etiology, with genetic,[6-9] demographic,[10-12] and acquired or modifiable components[13-16] that lead to progressive loss of articular cartilage and histologic changes in the subchondral bone and marrow. The incidence of symptomatic hip disease has been estimated to be 88 per 100,000 population, with an approximate prevalence of 10% in the United States.[17,18]

Osteonecrosis is a disease characterized by the interruption of the normal osseous blood supply leading to bone death. Unfortunately, the inadequate healing response leads to femoral head collapse and to later degenerative arthritis.[4] The incidence of hip osteonecrosis in at-risk populations is as high as 2.51 per 100,000, with early studies estimating up to 20,000 new diagnoses each year in the United States.[4,19,20] However, the prevalence is typically 6% to 15% but may be as high as 52% in patients treated with high-dose corticosteroids.[21-23]

Rapidly progressive osteoarthritis is a less commonly reported hip arthropathy, with fewer than 20 published reports in the literature. The incidence of this disease has not been accurately determined, but some studies have reported a 10% to 18% prevalence in patients referred to specialist centers.[24,25] It presents with the same symptoms as arthritis but is characterized by rapid joint space loss, chondrolysis, and sometimes marked femoral head and acetabular destruction as a late finding, often occurring within 6 to 24 months. The condition was first described by Lequesne,[26] who defined it as greater than 2 mm of joint space loss per year in the setting of pain and disability. Although the exact pathogenetic mechanism is

unknown, it has been hypothesized that subchondral insufficiency fractures in patients with physiologically weakened bone are the primary cause.[27]

Clinical Aspects

Clinically, osteoarthritis, osteonecrosis, and rapidly progressive osteoarthritis all may present with findings of pain, joint stiffness, and general disability, but each have distinct demographic predilections and distributions of joint involvement. Table 1 lists key epidemiologic and clinical findings associated with these diseases.

Table 1

Key Epidemiologic and Clinical Findings of Osteoarthritis, Osteonecrosis, and Rapidly Progressive Osteoarthritis

Finding	OA	ON	RPOA
Presentation	Slow onset	Pain early	Pain late
History	Pain at exertion	Rest pain, eventually constant pain	Pain at rest and exertion
Age, y	>60	<40	60-70
Sex, F:M	1.6:1	Equal	10:1
Bilaterality, %	10-30	⩾80	5-30
Other joint involvement	Yes (20%)	Yes (80%; hip>knee>shoulder>ankle)	No
Dead bone	Secondary	Primary	Secondary
Incidence[a]	Common (10%; ⩾20 million)	Intermediate (1%-15% of OA; 1 million)	Rare (10-20,000)

Abbreviations: OA, osteoarthritis; ON, osteonecrosis; RPOA, rapidly progressive osteoarthritis.
[a]*Reported as annual incidence in the United States.*

Demographics

Osteoarthritis and rapidly progressive osteoarthritis are more common in women and tend to manifest in the sixth decade of life or later. Osteonecrosis is more common in patients younger than 40 years and has no sex preference. However, acquired risk factors for osteonecrosis, such as alcohol abuse, smoking, and trauma, are more common in men, whereas inflammatory diseases, such as systemic lupus erythematosus, are more commonly found in women. Thus, the sex predilection in osteonecrosis is highly influenced by associated risk factors.

Risk Factors

Risk factors for osteoarthritis include advanced age and, in the case of hip osteoarthritis, patient activity and weight to a smaller degree (as compared with knee osteoarthritis).[11-13] Patients who have osteonecrosis often have an underlying autoimmune disease, blood dyscrasia (eg, malignancy or coagulopathy), or a history of alcohol abuse, smoking, radiation therapy, or treatment with corticosteroids. Although no definitive associated factors for rapidly progressive osteoarthritis have been identified, it is believed that osteopenic women are most at risk.[27]

Multiple Joint Involvement

Bilateral joint involvement is a feature of all 3 diseases but is most common in osteonecrosis, with more than 80% of patients demonstrating bilateral disease.[28,29] Bilateral joint involvement is seen in up to one-third of patients with osteoarthritis or rapidly progressive osteoarthritis; moreover, in the setting of rapidly progressive osteoarthritis, the contralateral hip may have an alternative diagnosis of osteoarthritis. Osteoarthritis and osteonecrosis can occur in other joints. Several studies have noted the risk of contralateral disease progression to THA for osteoarthritis to be approximately 20%, with common risk factors including young age and increasing disease severity.[25,30] However, in a study of 322 patients with osteoarthritis by Sayeed et al,[30] those who had the greatest clinical and radiographic disease severity had a 97% chance of progression to the need for THA.

Osteonecrosis is most frequently observed in the hip, followed by the knee, shoulder, and ankle. The incidence of knee osteonecrosis is approximately 10% of hip osteonecrosis. Conditions similar to rapidly progressive osteoarthritis but involving other joints have not been definitively reported. Although 1 case report describes rapid articular destruction about the knee, this occurred in a patient with hepatitis B who, on histological evaluation, had hallmarks indicative of a Charcot joint.[31] Shoulder involvement has been reported in several case reports that describe rapid chondrolysis and destruction of the humeral head and has been variably called rapidly destructive arthrosis, idiopathic osteolysis, or Gorham's disease, among many others.[32,33] A recent case report of rapid destruction of the humeral head by Tokuya et al[34] noted the presence of subchondral insufficiency fracture and granuloma formation on histologic examination.

Thus, it is possible that rapidly progressive osteoarthritis is found in multiple joints, but more studies are required to determine the incidence and early radiographic characteristics.

Diagnosis

The diagnosis of all 3 diseases is based on a combina-

Table 2

Diagnostic Modalities Used for Guiding Treatment

Modality	OA	ON	RPOA
Clinical examination	Chronic pain, joint stiffness	Subacute pain, joint stiffness less common	Variable (present after radiographic narrowing or femoral head destruction)
Plain radiographs	AP, lateral	AP, lateral, PA bilateral weight bearing	AP, lateral
MRI	Not indicated	Yes (changes before plain radiographs)	Yes (changes before plain radiographs)
Bone scan	Not indicated	Not indicated (misses up to 30% of lesions)	Unknown
Histology	Not indicated	Not indicated	H&E staining[a]

Abbreviations: AP, anteroposterior; H&E, hematoxylin-eosin; MRI, magnetic resonance imaging; OA, osteoarthritis; ON, osteonecrosis; PA, posteroanterior; RPOA, rapidly progressive osteoarthritis.
[a]*Used to confirm diagnosis at arthroplasty.*

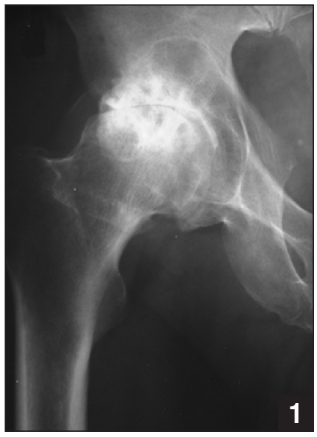

Figure 1: Anteroposterior radiograph of the right hip showing end-stage osteoarthritis with complete loss joint space, osteophyte formation, and subchondral cysts.

tion of clinical, radiographic, and magnetic resonance imaging (MRI) findings. Although these conditions can be distinguished by plain radiographs alone, differences often become evident only in later stages, typically following femoral head collapse. An important treatment implication of a delayed diagnosis is the inability to attempt joint-preserving procedures, which are particularly important for young patients. In the setting of equivocal clinical findings, the test of choice is MRI, which can be used early in the disease course and can help rule out other diagnoses.[35]

Bone scans are not indicated for osteoarthritis and osteonecrosis due to poor sensitivity and specificity. In the setting of oligofocal (2 or fewer joints involved) or multifocal osteonecrosis (3 or more joints involved), bone scanning detected 56% of histologically confirmed lesions compared with MRI.[36] The role of bone scans in the diagnosis of rapidly progressive osteoarthritis is also unknown. Histologic evaluation is the definitive diagnostic test for rapidly progressive osteoarthritis, but currently it is only performed at the time of surgery and acts more as a confirmatory test. All 3 conditions have specific histopathologic findings.[27,37-39] A summary of common diagnostic modalities is listed in Table 2.

Radiographic Findings

Plain Radiographs

Radiographic disease progression for osteoarthritis was described in detail by Kellgren and Lawrence[40] and consists of joint space loss, osteophyte formation, subchondral cysts, and sclerosis (Figure 1). Disease progression for osteonecrosis was similarly described by Arlet and Ficat,[41] consisting of 4 stages: normal hip with no radiograph findings but diagnosed on MRI (stage 1); radiographically evident disease with femoral head lucencies or sclerosis (stage 2); a crescent sign within the femoral head, which is indicative of late-stage disease (stage 3); and acetabular involvement and marked joint space narrowing (stage 4).

Unlike osteoarthritis, joint space narrowing in osteonecrosis is a late finding (Figure 2). Rapidly progressive osteoarthritis does not currently have a classification system, and based on the current authors' clinical experience with this entity, they propose a classification system. Current criteria for diagnosis are greater than 2 mm of joint space narrowing per year as originally described by Lequesne.[26]

In most cases, only rapid joint space narrowing, but no rapid femoral head dissolution or acetabular bone loss, is observed, which would be termed rapidly progressive osteoarthritis type 1. In cases of severe forms of this disease that have been reported in the literature, patients often initially presented with no radiographic signs of disease or mild narrowing and reporting groin pain. The disease process was observed to progress so rapidly that follow-up radiographs taken within 6 to 18 months following initial presentation demonstrate massive femoral head destruction.

In the most severe cases, the native hip may appear radiographically similar to a Girdlestone resection.[42] The hips have femoral head and acetabular destructive changes with severe joint degeneration and femoral head subluxation (Figure 3). The authors would characterize these cases as rapidly progressive osteoarthritis type 2. This may have the appearance of a Charcot-type joint, but these patients typically have atrophic changes rather than hypertrophic osteoarthritis and the hips are more painful. This is in contradistinction to Charcot-type joint disease, which is painless and in later stages presents radio-

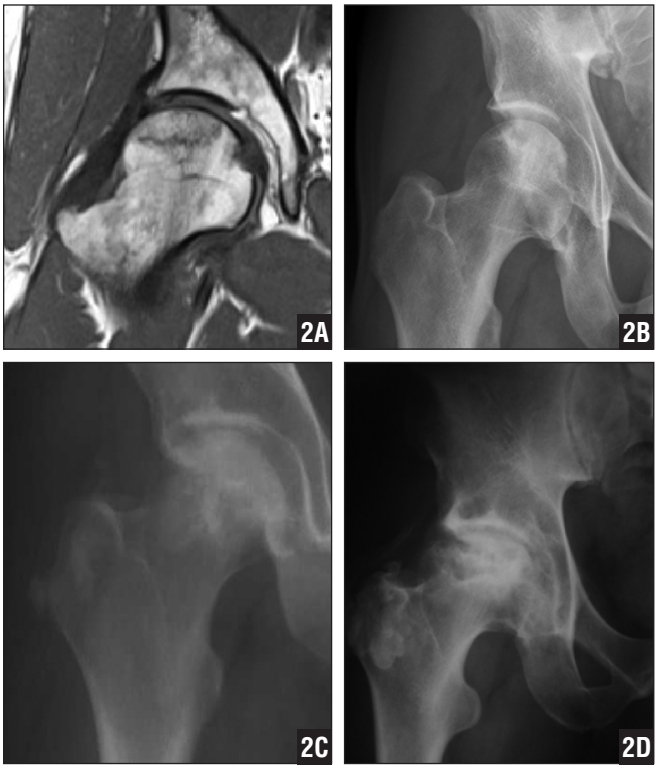

Figure 2: Coronal magnetic resonance image showing early (stage 1) osteonecrosis (A). Anteroposterior radiographs showing osteonecrosis with early involvement limited to the femoral head (stage 2) (B), with a subchondral fracture with crescent sign (stage 3) (C), and with acetabular involvement (stage 4) (D).

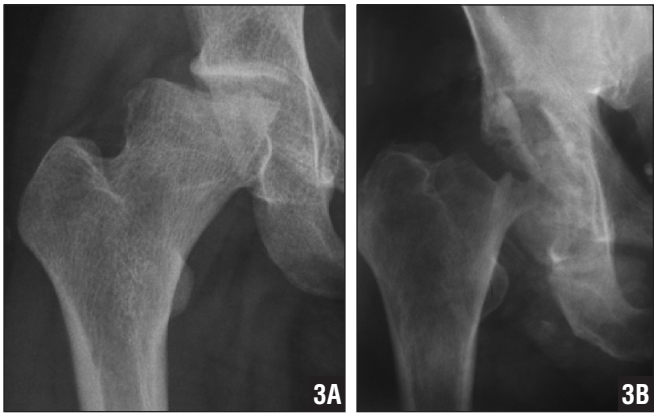

Figure 3: Anteroposterior radiographs of 2 patients with rapidly progressive hip disease resulting in partial (A) and complete (B) destruction of the femoral head and acetabulum.

graphically with disorganized consolidation and remodeling rather than bone loss.[43]

Magnetic Resonance Imaging

Magnetic resonance imaging can differentiate between osteoarthritis, osteonecrosis, and rapidly progressive osteoarthritis early in the disease course (Figures 4-6). It is not typically used for the diagnosis of osteoarthritis or rapidly progressive osteoarthritis, but is the test of choice for the diagnosis of early-stage osteonecrosis lesions, and it has a reported sensitivity and specificity greater than 90%.[44] Standard examination techniques include coronal and sagittal MRI obtained with fast spin-echo T2-weighted fat-suppressed, fast spin-echo T1-weighted, and short tau inversion recovery sequences.[35,37] Contrast-enhanced imaging with gadolinium is not necessary for osteoarthritis or osteonecrosis but has been described in the literature for rapidly progressive osteoarthritis.[35] A summary of MRI findings for these conditions is listed in Table 3.

Osteoarthritis presents as high signal intensity lesions on T2-weighted images or low signal intensity lesions on T1-weighted images in the superior, weight-bearing portion of the femoral head. These lesions represent bone marrow edema and are characteristically ill defined, with no clear border or demarcating features.[37,45]

Osteonecrosis has 3 characteristic lesions observed on MRI. Early stages present as well-defined, serpentine, high signal intensity lesions on T2-weighted sequences (low signal intensity lesions on T1-weighted sequences), which represent bone marrow edema. Intermediate stages have poorly defined serpentine lesions with large areas of diffuse high signal intensity. Later stages of the disease present as more diffuse areas of edema with foci of necrosis. These lesions are visible as areas of high signal intensity (edema) surrounding foci of low signal intensity (necrosis) on T2-weighted sequences.[46] In a prospective trial of 179 hips screened for osteonecrosis with MRI, Khanna et al[47] demonstrated an 98.9% reliability with using MRI as a screening tool to detect early osteonecrosis and determine the extent of involvement.

Rapidly progressive osteoarthritis presents with characteristic linear lesions early in the disease process, as opposed to the serpentine lesions seen in osteonecrosis. These linear hypointense lesions are observed on T1-weighted sequences in the weight-bearing portion of the femoral head, parallel to the articular surface, and likely represent subchondral fractures. High signal intensity lesions (edema) appear late, are ill defined with no clear border, and are often observed in the femoral neck or peripheral tissues (Figure 6).[35]

Histopathology

Osteoarthritis presents with histologic evidence of damage to articular cartilage, subchondral bone, and femoral head bone marrow. The subchondral bone and marrow surrounding an area of degenerated cartilage has necrosis-like and edema-like features. The area closest to the arthritic lesion has an area of marrow necrosis (usually less than 25% of the head) and vascular fibrosis, whereas areas more distant have edema-like features with fatty bone marrow but normal trabeculae and blood vessels.[37]

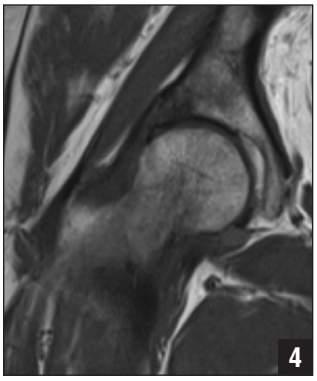

Figure 4: Coronal T1-weighted magnetic resonance image of hip osteoarthritis showing joint space narrowing, thinning of the articular cartilage on the femoral head, and a small cyst in the acetabulum.

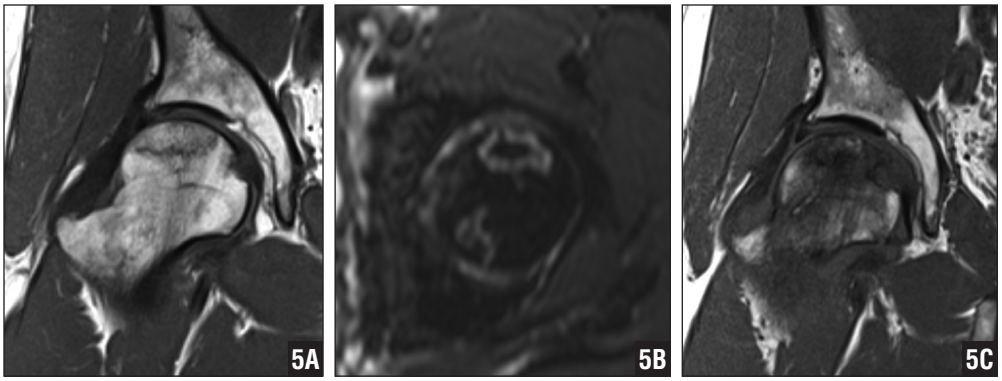

Figure 5: Magnetic resonance images of a patient with precollapse (stage 1) osteonecrosis showing serpentine lesions that appear hypointense on T1-weighted coronal sequences (A) and hyperintense on T2-weighted axial sequences (note the congruity of the femoral head) (B) and late-stage osteonecrosis with a diffuse hypointense signal in the femoral head and subtle flattening of the femoral head (C).

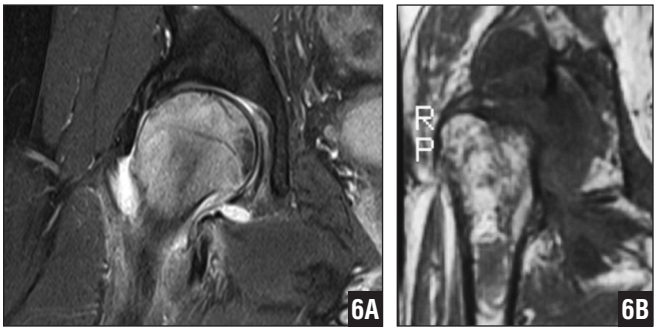

Figure 6: Coronal magnetic resonance images of a patient with rapidly progressive hip disease showing early disease on the T2-weighted image with subchondral fracture (linear hypointense signal) and hyperintense signal representing edema (A) and late disease on the T1-weighted image following femoral head destruction showing a diffuse hypointense signal involving the greater trochanter and extending past the calcar.

Histologic features of osteonecrosis have been previously described by Arlet et al.[38] Four characteristic stages are observed: bone marrow edema (stage 1); bone marrow necrosis (stage 2); fibrosis of the necrotic marrow (stage 3); and a reparative stage consisting of appositional bone formation (stage 4).[38,39] Histopathologic signs of necrosis include thinning of trabeculae, an empty Howship's lacunae, and a general paucity of hematopoietic cells. Bone marrow findings include the presence of varying proportions of edema, necrosis, and granulation tissue, depending on the stage. Fibrosis and calcification may also be observed within the marrow. Marrow edema will present as a faintly eosinophillic fluid, while marrow necrosis presents as fat necrosis, often with adjacent dead trabecular bone.[39]

Unlike the avascular picture seen in osteonecrosis, rapidly progressive osteoarthritis is hypervascular and has some histologic similarities to hypertrophic nonunions (Figure 7). Common findings are fractured trabeculae, areas of prominent granuloma formation with embedded bone and cartilage, and callus formation in the marrow space. Yamamoto et al[27] examined bilateral hips in a patient with rapidly progressive osteoarthritis and determined that a subchondral fracture was present in both, along with superimposed callus formation and secondary osteonecrosis. This led the authors to conclude that subchondral insufficiency fractures may be the primary cause in this disease.[27] This is consistent with MRI findings of subchondral fracture in almost half of the examined patients in a study by Boutry et al.[35]

TREATMENT

Nonsurgical Management

Joint preservation is the primary goal in all forms of hip arthropathy, especially with young patients. Osteoarthritis is commonly treated with lifestyle modification, analgesic medications, and corticosteroid injections, all of which may be effective in delaying the time to arthroplasty.

Osteonecrosis treatment has been investigated with lipid-lowering agents, prostacylcin analogues, anticoagulants, and bisphosphonates. Theoretical advantages for these modalities include lowering cholesterol levels because high levels of blood lipids have been associated with osteonecrosis, whereas antiplatelet medications may improve bone vascularity. Bisphosphonates may improve osteoblastic, and favorable results have been reported[48]; however, recent reports of atypical subtrochanteric femur fractures in patients treated for osteoporosis has resulted in a safety review by the US Food and Drug Administration, which may temper their use.[48] Shock wave therapy and electrical stimulation have also been proposed, but as with medical treatment, lower failure rates are observed with minimally invasive, bone-preserving surgical techniques for early-stage osteonecrosis.[49]

Unlike the prior osteoarthritis and osteonecrosis, rapidly progressive osteoarthritis does not appear to have effective nonoperative treatment modalities. Villoutreix et al[50] evaluated corticosteroid injections and activity modification with restricted weight bearing in 28 patients with rapidly progressive osteoarthritis. No difference in the need for definitive treatment was noted, with 20 of 28 patients undergoing THA within 1 year of symptom onset (mean, 6.2 months; range, 0.3-11 months).[50]

Table 3

Summary of Characteristic Magnetic Resonance Imaging Findings

Lesion	OA	ON	RPOA
Early	Edema; T1, diffuse low-intensity lesions; T2, diffuse high-intensity lesions; location, weight-bearing portion of femoral head	Edema; T1, serpentine low-intensity lesions; T2, serpentine high-intensity lesions; location, any; orientation, random	Subchondral fracture; T1, linear low-intensity lesions; location, weight-bearing portion of femoral head; orientation, parallel to articular surface
Late	Subchondral cysts, fibrosis, edema; T2, expanded diffuse high-intensity area	Edema, necrosis; T2, diffuse high-intensity lesions (edema) surrounding hypointense center (necrosis); location, any	Edema; T2, diffuse high-intensity lesions (edema); location, femoral neck and peripheral tissues
End-stage[a]	Edema, necrosis	Edema, necrosis	Edema, necrosis

Abbreviations: OA, osteoarthritis; ON, osteonecrosis; RPOA, rapidly progressive osteoarthritis.
[a]*All end-stage lesions may appear the same.*

Surgical Management

Total hip arthroplasty for end-stage osteoarthritis is the standard of care, and multiple stem, cup, and fixation options are currently available for orthopedic surgeons, many with excellent clinical results and more than 95% 10-year survivorship.[2]

Treatment options for osteonecrosis include joint preservation in early, precollapse stages (Association Research Circulation Osseous [ARCO] stages 1-2), and THA in postcollapse stages (ARCO stages 3-4). Precollapse treatment options include core decompression with or without bone grafting, percutaneous drilling, bone grafting with vascularized or nonvascularized grafts, and osteotomy.[51] Core decompression prevents the need for further surgery in approximately 60% to 80% of patients and, if used in combination with a percutaneous technique, is an outpatient procedure with small, cosmetically pleasing incisions and has a lower risk of subtrochanteric femur fractures.[52]

Nonvascularized and vascularized bone grafting is indicated for all lesions, especially for those not amenable to core decompression, and in select cases for early postcollapse stages. For late stages of this disease, the treatment of choice is THA or, in a subset of select young, active patients, resurfacing arthroplasty.

Sayeed et al[53] reported outcomes of THA and hip resurfacing in 33 patients aged 25 years or younger with osteonecrosis. The authors reported excellent clinical outcomes and a 93% and 100% 7.5-year survivorship, respectively.[53] Similar survivorship was reported by Byun et al[54] at 6-year follow-up in 41 patients younger than 30 years treated with THA.

Rapidly progressive osteoarthritis is currently only treated with THA. Numerous stem types and fixation methods have been described in the literature, and studies with a mean follow-up longer than 5 years have demonstrated a greater than 95% survivorship.[55-58] Unlike in osteoarthritis and osteonecrosis, acetabular defects are common at the time of surgery for rapidly progressive osteoarthritis. In a study by Peters and Doets,[58] 3 of 8 patients had acetabulae classified as 3A by the system described by Paprosky et al.[59]

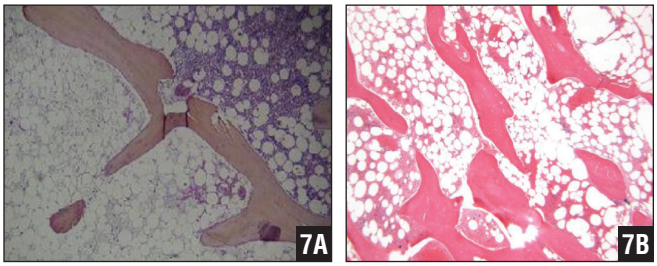

Figure 7: Hematoxylin-eosin stains of an osteoarthritic hip demonstrating fatty replacement of the marrow (A) and osteonecrosis demonstrating empty lacunae (signifying bone death) and a generalized lack of hematopoietic cells (B) (original magnification ×10).

Conclusion

Osteoarthritis, osteonecrosis, and rapidly progressive osteoarthritis are hip arthropathies that may present with clinically similar pictures. Patients commonly present with groin pain and limited mobility in later stages of the disease. Although demographic factors such as age and sex can help distinguish between these diseases, radiographic imaging is necessary to confirm the diagnosis.

In patients with rapidly progressive osteoarthritis, the authors classify those with rapid joint space narrowing but no bone loss as rapidly progressive osteoarthritis type 1 and those with evidence of femoral head dissolution or acetabular bone loss as rapidly progressive osteoarthritis type 2.

In patients who are suspected to have osteonecrosis or rapidly progressive osteoarthritis, MRI is the diagnostic test of choice early in the disease course. Distinct radiographic findings on MRI include diffuse edema for osteoarthritis, serpentine lesions representing edema in osteonecrosis, and linear subchondral densities parallel to the articular surface in rapidly progressive osteoarthritis, which represents a subchondral fracture. If radiographs are equivocal, confirmation of the presumptive diagnosis, particularly in the case of rapidly progressive osteoarthritis, is done with histopathologic examination of the femoral head following THA. All 3 diseases have distinct histologic features, with necrosis-like and edema-like patterns present in osteoarthritis, an avascular picture with empty lacunae and few hematopoietic cells with osteonecrosis, and a hypervascular picture with granuloma formation in rapidly progressive osteoarthritis.

Treatment consists of joint preserving nonsurgical or surgical options of osteoarthritis and precollapse stages of osteonecrosis. Definitive surgical treatment with THA is reserved for patients who have failed nonoperative treatment methods and have end-stage osteoarthritis, those with postcollapse stages of osteonecrosis, and those with rapidly progressive osteoarthritis.

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